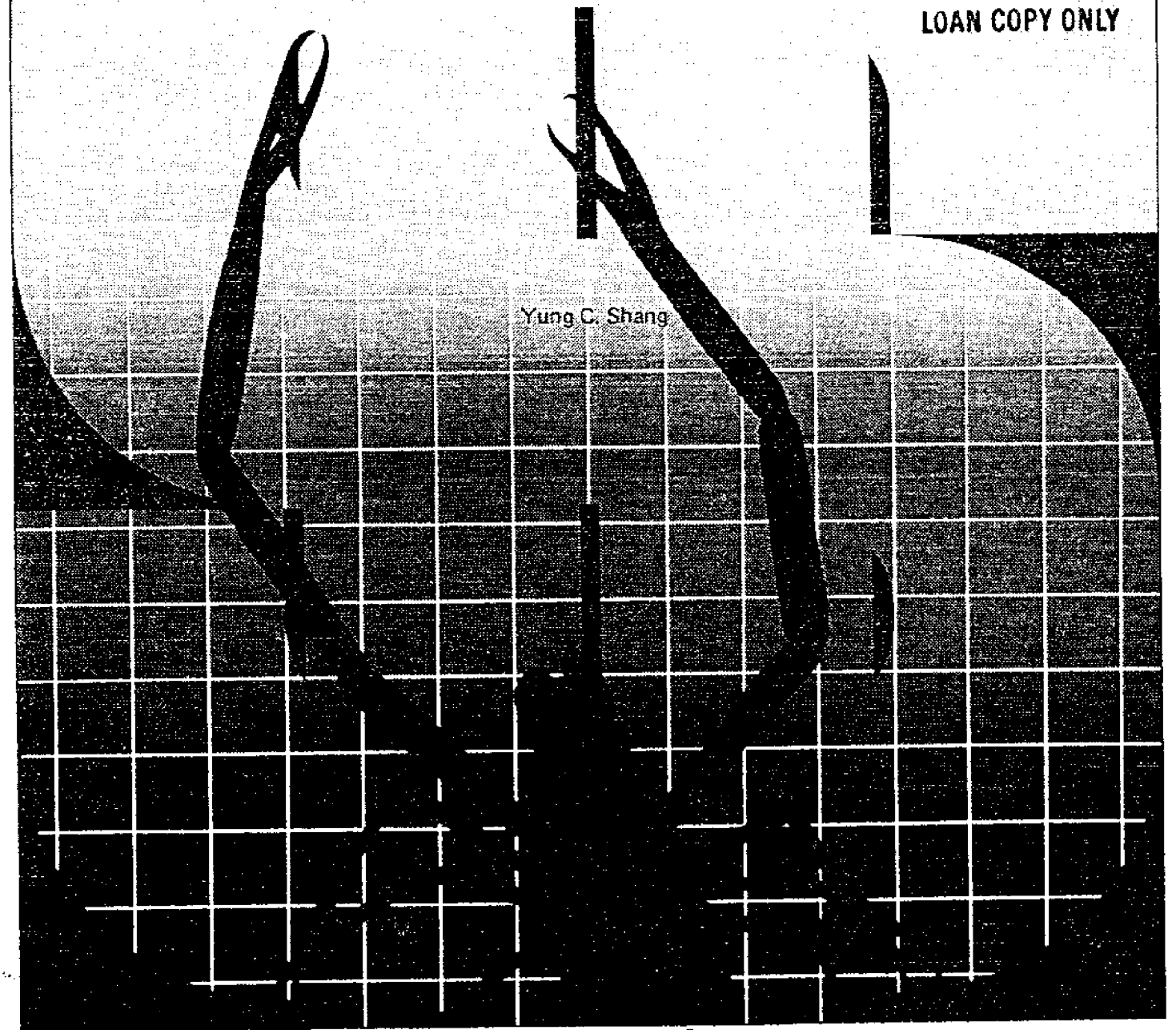
UNIHI-SEAGRANT-MR-81-07

# FRESHWATER PRAWN (MACROBRACHIUM ROSENBERGII) PRODUCTION IN HAWAII: PRACTICES AND ECONOMICS





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# FRESHWATER PRAWN (*MACROBRACHIUM ROSENBERGII*) PRODUCTION IN HAWAII: PRACTICES AND ECONOMICS

by

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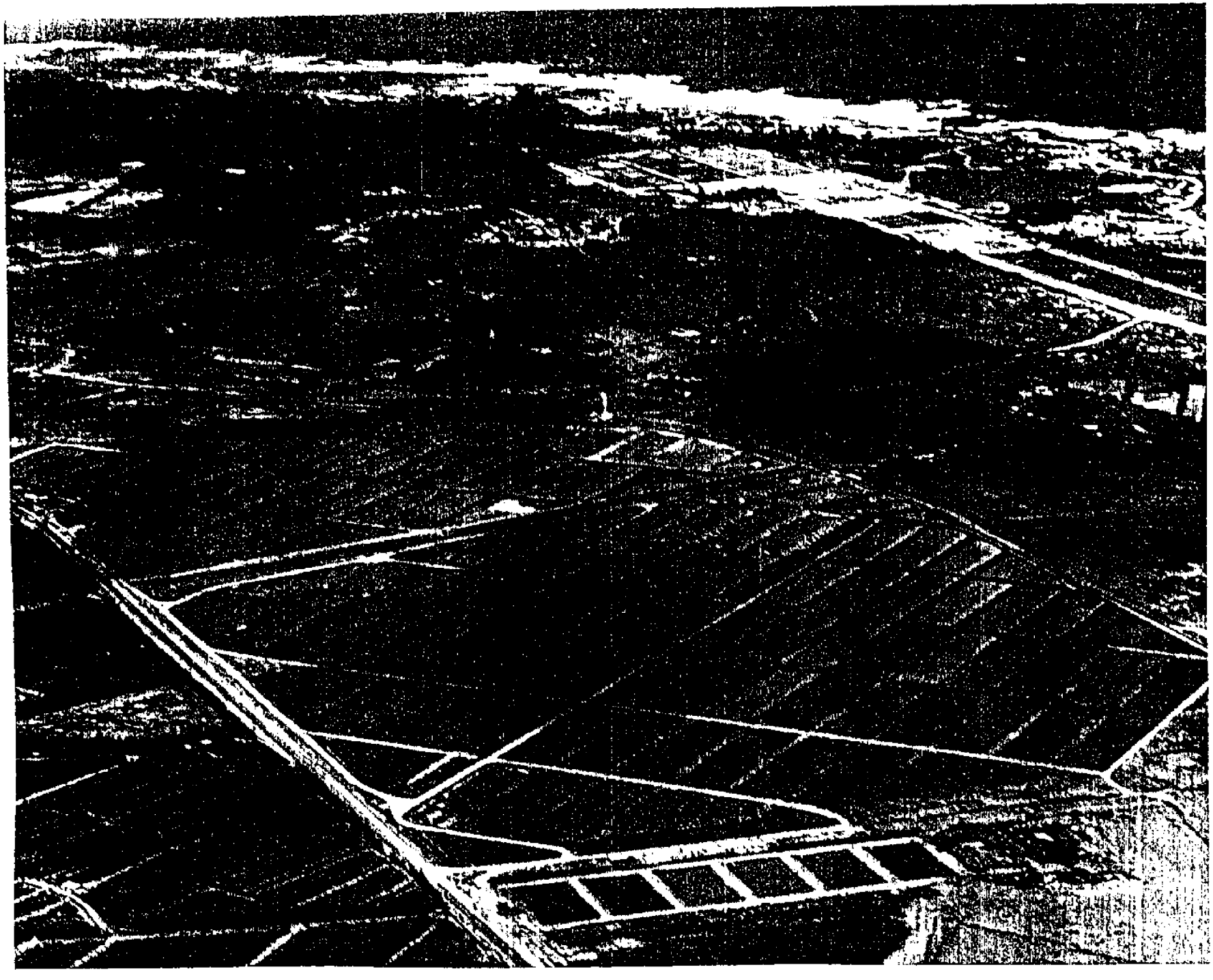

Lowe Aquafarm, the largest freshwater prawn farm in the United States, occupies a 118-acre site at Kahuku on the north shore of Oahu. (Fred Ball photo)

## ACKNOWLEDGMENTS

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# INTRODUCTION

## Purpose of the study

Freshwater prawn farming is continuing to expand in Hawaii, and as a consequence the state has become a world center for information and expertise on the culture of *Macrobrachium rosenbergii*. To keep abreast of the many changes which have occurred since the results of an earlier study by Shang and Fujimura were published in 1977, another economic study was conducted in 1980. This study included (1) a review of the trends in the development of the freshwater prawn industry in Hawaii; (2) an examination of the evolution or development of prawn grow-out systems and of system components, e.g., site selection, pond design, stocking, feeding, harvesting, and processing; and (3) an analysis of the costs and returns of different farm sizes from data collected through a survey of prawn farms in Hawaii. The information, as presented in this report, is not only important for prospective investors in this industry, but also for policymakers.

## The species for culture

Over a hundred species of *Macrobrachium* exist in the world but most freshwater prawn culture is synonymous, at present, with the culture of *M. rosenbergii*. The success in determining the life cycle of this species by Dr. S.W. Ling, former Food and Agriculture Organization aquaculture specialist in the Far East, and in developing techniques for both mass postlarvae production and grow-out systems by Mr. Takuji Fujimura and co-workers at the Anuenue Fisheries Research Center (AFRC) resulted in the Anuenue stock of *M. rosenbergii* being the major source of prawn postlarvae for culture. More than 2 million postlarvae were produced in 1974, and a year-round production capacity of between 25 and 30 million is currently possible at the state hatchery.

*Macrobrachium rosenbergii* was chosen since there are a number of advantages of culturing this species over many other species of *Macrobrachium*. It adapts to a relatively wide temperature range from a minimum of 15°C (59°F) to a maximum of 35°C (95°F), with maximum growth occurring at temperatures near 31°C (87.8°F) (Shang and Fujimura, 1977). The female carries and cares for her eggs, thus resulting in a relatively high hatching rate. The species has a relatively short larval life of 22 to 35 days at about 31°C to 26°C (87.8°F to 78.8°F), respectively (Shang and Fujimura, 1977). It is also a fast growing omnivore, feeding on both animal and plant material.

The Anuenue Fisheries Research Center's practice of sharing techniques and providing broodstock has facilitated freshwater prawn farming in many other parts of the world, particularly in Southeast Asia and Central America. Nearly 27 countries now have experimental hatcheries, and several countries are engaging in commercial production of prawn (Appendix A). At present, there is a $3.5 million prawn industry in Thailand, with over 455 farms, 375 hectares of pond area, and an annual production level of about 350 tons (Department of Fisheries, Thailand, 1980). Freshwater prawn farming is also expanding in Taiwan where there are 30 commercial farms totaling 165 hectares of pond area producing 65 tons annually (Liao and Chao, 1980).

In Hawaii, the development of the freshwater prawn industry has increased from 0.6 hectare (1.5 acres) of ponds in 1970 to about 126 hectares (310 acres) in 1980 (Table 1). The latter figure represents the 20 farms yielding an estimated 136,116 kilograms (300,000 pounds) of prawns. Although a few farms, including one of the larger operations, terminated operation during the past decade, there are indications from prospective investors which point to further expansion of this industry. A large Hawaiian company has plans to develop

up to 162 hectares (400 acres) of ponds. Construction began in the latter part of 1980. In addition, plans to expand several existing farms have been developed.

TABLE 1. LAND AREA AND PRODUCTION OF FRESHWATER PRAWNS IN HAWAII, 1974-80

| | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980* |
|---|---|---|---|---|---|---|---|
| Total Land Area in Hectares (in acres) | 9.7 (24.1) | 9.9 (24.4) | 16.2 (40.0) | 78.3 (193.5) | 125.2 (309.5) | 126.5 (312.5) | 125.5 (310.0) |
| Production in Kilograms (in pounds) | 4,901 (10,805) | 18,064 (39,824) | 21,358 (47,086) | 25,473 (56,158) | 54,514 (120,183) | 95,455 (210,000) | 136,116 (300,000) |

*Data obtained after 1980 survey, but are included to give more current land area and production figures.

Individual prawn farm sizes in Hawaii range from a minimum of less than 0.4 hectare (1 acre) to a maximum of about 47 hectares (116 acres). However, only 2 of the 20 farms are considered relatively large in size (40 hectares or 100 acres or more). About 60 percent of all existing farms are less than 4 hectares (10 acres) in size. The rest are between 6 and 14 hectares (15 and 35 acres) in size.

Individual pond sizes vary from nearly 0.1 hectare (0.25 acre) up to 1.5 hectares (3.75 acres) per pond as shown in Table 2. Approximately 58 percent of the existing prawn ponds are 0.4 hectare in size.

Among the existing prawn operations, eight are full-time enterprises. Others combine prawn farming with the production of agricultural crops and/or other business activities. Fourteen farms (70 percent) began operation within the past three years; five farms started four to seven years ago. Only one farm has been in operation for about 10 years.

## POND GROW-OUT SYSTEMS

### Site selection

The prawn farmers interviewed were asked to suggest what factors they consider to be important in selecting a farm site for raising prawns alone or in combination with other agricultural activities. They felt that water quality and quantity, soil type, topography, cost of land, and climatic conditions should be considered during the initial planning stages.

The quality and quantity of available water is important. A sudden change in water supply or quality can kill or otherwise adversely affect a pond prawn population. Anuenue Fisheries Research Center data suggest an average water flow rate of approximately 75 liters/minute/0.4-hectare pond (20 gallons/minute/1-acre pond) for a freshwater prawn grow-out system. Most of the farms using wells do not keep water flow at that rate continuously, but usually for only a few hours a day. Farms obtaining water from either a river or stream (60 percent) are more likely to have continuous water flow.

Another important consideration is the farm site soil. It should be more than 1 meter deep and nearly impermeable to water. The soil should not contain residual chemicals or poisonous agents from pesticides and herbicides used in earlier agricultural operations. Most

TABLE 2. NUMBER OF PRAWN PONDS IN VARYING SIZES IN HAWAII

| Pond Size in Hectares (in acres) | No. of Ponds | Percentage of Total |
|---|---|---|
| 0.10 or less (0.25 or less) | 11 | 5 |
| 0.11 to 0.20 (0.26 to 0.50) | 15 | 7 |
| 0.21 to 0.30 (0.51 to 0.75) | 7 | 3 |
| 0.31 to 0.40 (0.76 to 1.0) | 129 | 58 |
| 0.41 to 0.50 (1.01 to 1.25) | 6 | 3 |
| 0.51 to 0.60 (1.26 to 1.50) | 1 | 0.5 |
| 0.61 to 0.70 (1.51 to 1.75) | 5 | 2 |
| 0.71 to 0.80 (1.76 to 2.0) | 6 | 3 |
| 0.81 to 0.91 (2.01 to 2.25) | 5 | 2 |
| 0.92 to 1.01 (2.26 to 2.50) | 1 | 0.5 |
| 1.02 to 1.11 (2.51 to 2.75) | 3 | 1 |
| 1.12 to 1.21 (2.76 to 3.0) | 0 | 0 |
| 1.22 to 1.31 (3.01 to 3.25) | 31 | 14 |
| 1.32 to 1.41 (3.26 to 3.50) | 1 | 0.5 |
| 1.41 to 1.51 (3.51 to 3.75) | 1 | 0.5 |
| TOTAL | 222 | 100 |

Source: Personal interviews with local prawn farmers and personnel of the Anuenue Fisheries Research Center

of Hawaii's freshwater prawn farms are located in the northeastern section of the island of Oahu. Soil in this area is either composed of clay loam or silty clay. Bedrock is normally found at depths greater than 1.5 meters (5 feet).

Topography is also important. A site ought to be relatively flat or minimally sloping mainly because construction can be accomplished much more easily, quickly, and cheaply on this type of terrain than on a sloped parcel of land. Currently, most of the prawn farming sites in Hawaii have been developed on relatively flat agricultural lands.

The cost of leasing or purchasing land must also be considered. Costwise, probably the land located in agricultural zones is most desirable because of its prevailing lower market value and the ease by which permits can be obtained for alternative uses such as aquaculture.

A final consideration for selecting a farm site is the climate of the area. For instance, fairly warm regions with gentle breezes are favorable since, all other things being equal, prawn rearing periods are shorter on farms located in such areas. A study completed in 1974 by Takuji Fujimura noted that ideal temperatures for raising freshwater Malaysian prawns range between 28.0°C and 31°C (82.4° and 87.8°F). Water temperatures recorded from November 18, 1971 to October 24, 1972 on two experimental ponds located in the northeastern section of Oahu (Table 3) can be considered typical for many farms in Hawaii. The minimum temperatures recorded during winter months in some areas of Hawaii are generally considered too cold for prawn farming and result in slow prawn growth rates.

TABLE 3. WATER TEMPERATURE RECORDS FROM TWO EXPERIMENTAL PONDS LOCATED IN THE NORTHEASTERN SECTION OF OAHU, NOVEMBER 18, 1971 TO OCTOBER 24, 1972

| Month | Degrees | | | | | |
|---|---|---|---|---|---|---|
| | Minimum | | Maximum | | Average | |
| | C° | F° | C° | F° | C° | F° |
| 1971 | | | | | | |
| November | 22.8 | 78.0 | 25.0 | 77.0 | 23.7 | 74.17 |
| December | 21.1 | 70.0 | 25.0 | 77.0 | 22.9 | 73.2 |
| 1972 | | | | | | |
| January | 19.4 | 66.9 | 25.6 | 78.08 | 22.8 | 73.0 |
| February | 19.4 | 66.9 | 23.9 | 75.0 | 21.9 | 71.4 |
| March | 21.1 | 70.0 | 28.3 | 82.9 | 24.2 | 75.6 |
| April | 21.1 | 70.0 | 26.1 | 79.0 | 23.6 | 74.5 |
| May | 25.0 | 77.0 | 28.3 | 82.9 | 26.5 | 79.5 |
| June | 24.4 | 75.9 | 28.9 | 84.0 | 26.9 | 80.4 |
| July | 25.0 | 77.0 | 28.9 | 84.0 | 26.9 | 80.4 |
| August | 26.1 | 79.0 | 31.1 | 88.0 | 28.5 | 83.3 |
| September | 25.0 | 77.0 | 28.3 | 82.0 | 26.5 | 79.5 |
| October | 23.9 | 75.0 | 27.8 | 82.0 | 25.7 | 78.3 |

Neglecting any of the aforementioned factors in selecting a proper site or location for prawn farming could prove extremely costly both during the initial developmental stages and in the long-term operation.

## Pond design

The principal determinants of pond design are economy of construction, contour of the land, and ease of harvesting and pond management. In Hawaii, most existing ponds are rectangular in shape and earthen-formed. The pond bottoms are relatively flat and well compacted with a slope of less than 1° toward the deeper end and with a sluice gate system constructed for periodic drainage of the ponds.

As mentioned earlier, most ponds are about 0.4 to 0.8 hectare (1 to 2 acres) in size, ranging from a minimum of 0.1 hectare (0.25 acre) to a maximum of 1.5 hectares (3.75 acres). Average water depth is between about 0.9 and 1.0 meter (3.0 and 3.5 feet). The width of the pond berms is about 3.05 to 3.66 meters (10 to 12 feet) with approximately 0.3 meter (1 foot) of the berms above the surface of the water. The sides have an inner slope ratio of 3:1 (horizontal:vertical) and an outer slope ratio of 2:1. Terrestrial vegetation is grown along the inner berm slopes to strengthen the walls against erosion, to provide shelter for the young and molting prawns, and to serve as a habitat in which many microscopic organisms thrive.

A preliminary study done by the University of Hawaii Agricultural Engineering Department concluded that a narrower, canal-type pond is more efficient for harvesting, feeding, and controlling prawns than the rectangular-shaped one (Gibson and Wang, 1977). In addition, the canal-type pond was estimated to be less expensive to construct. Farmers, however, do not appear interested in this design yet, and further field studies are needed to evaluate its efficiency.

## Stocking

At present, the average stocking rate used by most farmers in Hawaii is between 16 and 22 juveniles per square meter (1.5 and 2 juveniles per square foot) of water surface area. Stocking is normally done on an annual basis during the summer months, and the juveniles are stocked as soon as possible following metamorphosis.

One large-scale farm has recently added nursery facilities to its rearing ponds to produce postlarvae for stocking. It seems much easier to monitor and maintain optimum conditions in a small set of nursery ponds than a whole set of production ponds for an extended period of time after each stocking. This new stocking system is likely to reduce mortality in the grow-out ponds as well as increase production efficiency and may easily pay off the cost of adding a nursery system.

The Anuenue Fisheries Research Center which operates a publicly subsidized prawn hatchery on Sand Island provides free juveniles and extension services to participating prawn farmers during the first three years of their operation. After the third year, a fee of $8.00 per 1,000 juveniles is assessed.

Theoretically, continuous restocking after periodic harvests might result in higher yields of marketable prawns per pond. However, this practice has not yet been adopted by the farmers mainly due to the seasonal supply of juveniles from the state hatchery.

There are three other hatchery operations in Hawaii. Two produce juveniles only for their usage. The other sells juveniles to markets outside of Hawaii at a price of about $25.00 to $50.00 per 1,000 juveniles. This price includes the cost of packaging, handling, and delivery.

### Feeding

Nearly 60 percent of the local prawn farmers are currently using prawn pellets as feed. The pellets, consisting mainly of corn, soybean, meat and bone meal, and alfalfa, have a protein content of about 24 to 27 percent. The rest of the farmers use other types of feed, such as chicken broiler starter and gamecock feed.

Prawns are routinely fed on a daily basis. A rate of one-half gallon (1.8 kilograms) of feed per 0.4-hectare pond is recommended by the Anuenue Fisheries Research Center for the initial rearing period. This daily amount can be increased if the food disappears within a day or decreased if leftovers are evident. Most farmers, about 65 percent, keep feeding rates between 11.34 and 18.14 kilograms (25 and 40 pounds) per pond (after initial rearing period), depending on the age of the prawn. On the average, the daily feeding rate for a pond (0.4 hectare) is about 15.9 kilograms (35 pounds).

## HARVESTING AND PROCESSING

For most prawn farms in Hawaii, harvesting of market-sized animals (about 2 ounces) begins 6 to 10 months after initial stocking. Due to considerable heterogeneous growth of individual prawns in a pond, harvesting is done selectively. The usual process involves the use of three men to drag a 5-cm (2-inch) mesh monofilament net lengthwise across the pond. With this method, undersized prawns remain in the pond for future harvests. A 0.4-hectare pond can usually be harvested by a three-man crew in two to three hours. A few farms employ more men for harvesting, e.g., 26 percent employ four men and one farm uses a five-man crew. Currently, one of the larger farms is conducting tests using a prototype tractor-towed seine with a rigged live cage collector or bag held in place. Using this mechanized equipment developed by the University of Hawaii's Agricultural Engineering Department, a 0.4-hectare pond can be harvested in about 30 to 60 minutes with a four-man crew.

About 63 percent of the prawn farms in Hawaii are harvested every four weeks, whereas the other farms harvest their ponds once every two to three weeks. The annual yield per 0.4-hectare pond varies from season to season and between farms, ranging from less than 227 kilograms (500 pounds) to over 907 kilograms (2,000 pounds). The reasons cited by farmers for such variations in harvest are climatic fluctuations, the number and schedule of stocking, water quality, predation, the length of time a pond has been in operation, the amount of shade and shelter available to prawns, etc. Generally speaking, an average annual yield of 907 kilograms per 0.4-hectare pond is currently obtainable, under proper management, after two to three years of operation. This is much less than the estimated yield, based on experimental data used by Shang and Fujimura in their 1977 study. This production level is equivalent to a survival rate of only about 25 percent or 16,000 market-sized prawns from the 65,000 postlarvae stocked.

Once harvesting is completed, the prawns are usually delivered to wholesale or retail outlets (22 to 26 prawns per kilogram with heads on) and restaurants (15 to 20 prawns per kilogram with heads on) in one of four forms: live, chilled, blanched, and frozen. Live prawns are generally kept in holding tanks until sold. Ice-chilled prawns retain an acceptable quality for only about two to three days. Blanched prawns, quick killed in an ice slurry then dipped in 68.33°C water (155°F) water for about 15 seconds before being packed in ice, retain an acceptable quality for about three to four days. Prawns that have been frozen soon after harvesting have a shelf life of up to six months.

The Hawaii Prawn Producers Association was founded in 1979. The main purpose of this association is to foster the continued development of the Hawaiian prawn industry

through guiding state research and marketing and promotion efforts, as well as encouraging uniform production practices among growers (Lee, 1979). To date, the association has a membership of approximately 13 farmers.

## COSTS OF PRODUCTION

### Construction

Pond construction costs vary according to the topography of the site selected, the size of the farm being developed, and the size and shape of an individual pond. Current excavation and compaction costs for employing a licensed contractor to construct a rectangular-shaped 0.4-hectare earthen pond on a properly selected site is approximately $1.00 per 0.9 cubic meter (1 cubic yard) for earth moving and $2.00 per 0.9 cubic meter for construction and compaction of berms/embankments and the pond bottom, including the costs of pond design, permits, insurance, etc.

For this study, the construction cost for an earthen pond was estimated based on a 0.4-hectare pond with a total wetted area measuring 120.7 meters long x 33.5 meters wide x 0.9 to 1.2 meters deep (396 feet long x 110 feet wide x 3 to 4 feet deep) and based on the volume of cut equaling the volume needed for constructing the embankments. The total amount of land required for a 0.4-hectare pond farm is approximately 0.6 hectare (1.5 acres) or 146.7 percent of the wetted area. For a large size farm with numerous ponds, however, only one-half of the surrounding embankment is required for each pond. In this case, the total amount of land required for a 0.4-hectare pond is about 0.5 hectare (1.2 acres) or 117.6 percent of the wetted area (see Appendix B).

Moreover, due to economics of scale, excavation and compaction costs per 0.9 cubic meter for larger farms are lower. As the construction project expands in terms of total acreage, the aggregate work effort required decreases (Table 4).

TABLE 4. ESTIMATED EXCAVATION AND COMPACTION COSTS BY FARM SIZE

| | Farm Size | | | | |
|---|---|---|---|---|---|
| | 0.4 Hectare (1 Acre) | 4 Hectares (10 Acres) | 8 Hectares (20 Acres) | 20 Hectares (50 Acres) | 40 Hectares (100 Acres) |
| Excavation Cost per 0.9 cubic meter | $1.00 | $0.80 | $0.75 | $0.70 | $0.65 |
| Compaction Cost per 0.9 cubic meter | $2.00 | $1.60 | $1.50 | $1.40 | $1.30 |

About 40 percent of all prawn farmers in Hawaii hired licensed contractors to construct their ponds. The rest constructed their own ponds by renting, purchasing, or borrowing construction equipment. The cost for constructing a pond by renting heavy industrial equipment can be estimated using the following information:

1. Renting a medium-sized bulldozer at $2,500 per month plus a required insurance fee of $500
2. Using diesel fuel at a rate of 18.9 to 56.8 liters per day (5 to 15 gallons per day)

3. Hiring a unionized, construction equipment operator at the current wage rate of about $11.00 per hour

Only a few prawn farmers can operate a bulldozer, thus eliminating the need to hire a licensed operator. The cost of renting construction equipment and hiring an operator often exceeds the cost of hiring a licensed contractor to build the pond.

The cost for constructing a well, if the site selected does not have an available water supply, is high and dependent upon the size of a farm, the quantity of water required (per minute, per hour, or per day), and the depth required. For example, a 0.3-meter (1-foot) diameter well built by a licensed contractor currently costs $1,150 per meter ($350 per foot). If drilled to a greater depth than 60 meters (200 feet), the total cost will be at least $70,000, and possibly more.

Because there are public restrictions on well construction, a permit must be secured before drilling begins. The City and County of Honolulu's Board of Water Supply is the governing municipal body on Oahu which issues permits based strictly upon the available supply of water for uses other than human consumption. The neighbor islands have no well permit requirements. However, all the existing farms in Hawaii have had an available source of water at hand; therefore, the construction cost for a well is not included in the calculations.

For a water delivery system the cost per pond varies with the following:

1. The distance from the existing water supply to prawn pond(s)
2. The type(s) and sizes of pipe accessories used
3. The size and shape of a pond
4. Total farm size

Based on a 0.4-hectare pond measuring 120 meters long x 33 meters wide of the wetted area as mentioned earlier, only the purchasing cost for approximately 45 meters (148 feet) of PVC equipment is used in the calculations. The installation cost shall be assumed included during the initial construction of the earthen ponds. The size, and hence the cost, of PVC equipment increases as farm size increases.

In addition, the construction cost for a sluice gate system at the deeper end of a pond, which allows rapid discharging of water with minimal maintenance and easy regulation of water level, is about $800 per 0.4-hectare pond.

Lastly, the construction cost for a work and storage building is estimated for a 0.4-hectare and a 4.4-hectare farm at between $100 and $1,000 for an easily assembled metal hut sold by most major department stores. For 8, 20, and 40-hectare (20, 50, and 100-acre) farm sizes, the average market construction costs is about $20 per 0.09 square meter (1 square foot) by hiring a contractor. This generally includes a concrete foundation, prefabricated walls, and electrical wiring and water pipe installation.

The total average construction cost per 0.4-hectare pond varies with farm size. It costs about $7,000 per pond for a 0.4-hectare farm and about $6,400 for a 40-hectare farm (Table 5).

TABLE 5. ESTIMATED AVERAGE CONSTRUCTION AND EQUIPMENT COSTS PER 0.4-HECTARE POND BY FARM SIZE

| | Farm Size | | | | |
|---|---|---|---|---|---|
| | 0.4 Hectare (1 Acre) | 4 Hectares (10 Acres) | 8 Hectares (20 Acres) | 20 Hectares (50 Acres) | 40 Hectares (100 Acres) |
| Construction Costs | | | | | |
| Pond | $ 5,724 | $4,579 | $4,293 | $4,007 | $3,721 |
| PVC | 295 | 1,018 | 1,587 | 1,587 | 1,587 |
| Gate | 800 | 800 | 800 | 800 | 800 |
| Storage | 150 | 100 | 100 | 300 | 300 |
| Subtotal | 6,969 | 6,497 | 6,780 | 6,694 | 6,408 |
| Equipment Costs* | | | | | |
| Seine and net | 869 | 174 | 87 | 70 | 70 |
| Holding and transporting tanks | 400 | 100 | 50 | 40 | 30 |
| Portable pump | 300 | 60 | 30 | 24 | 18 |
| Mowing equipment | 300 | 1,000 | 500 | 200 | 100 |
| Truck | 7,000 | 700 | 350 | 300 | 220 |
| Freezer | -- | -- | -- | 200 | 200 |
| Water pump | -- | 150 | 150 | 120 | 90 |
| Oxygen meter | 700 | 70 | 35 | 28 | 14 |
| pH meter | 150 | 15 | 8 | 6 | 3 |
| Ice machine | -- | 300 | 150 | 60 | 30 |
| Miscellaneous | 486 | 129 | 75 | 52 | 39 |
| Subtotal | 10,205 | 2,698 | 1,435 | 1,100 | 814 |
| TOTAL | $17,174 | $9,195 | $8,215 | $7,794 | $7,222 |

Note: Estimated figures are derived from Appendix D

*Does not include the automatic feeder which costs about $400 to $2,000 and is used on only two farms

## Equipment

Major equipment needed on a farm include net, holding transportation tank, portable pump, mowing equipment, truck, freezer, water pump, ice machine, oxygen meter, pH meter, etc. The amount of equipment required per farm by farm size is summarized in Appendix C. The estimated average cost for equipment per 0.4-hectare pond varies also with farm size (Table 5 and Figure 1). The total cost of equipment decreases from $10,205 per pond for a 0.4-hectare farm to about $814 for a 40-hectare farm due to economies of scale.

The total construction and equipment cost per pond decreases with an increase in farm size. The cost per pond for a 0.4-hectare farm would be about $17,000, whereas it would be about $7,200 for a 40-hectare farm (Table 5 and Figure 1).

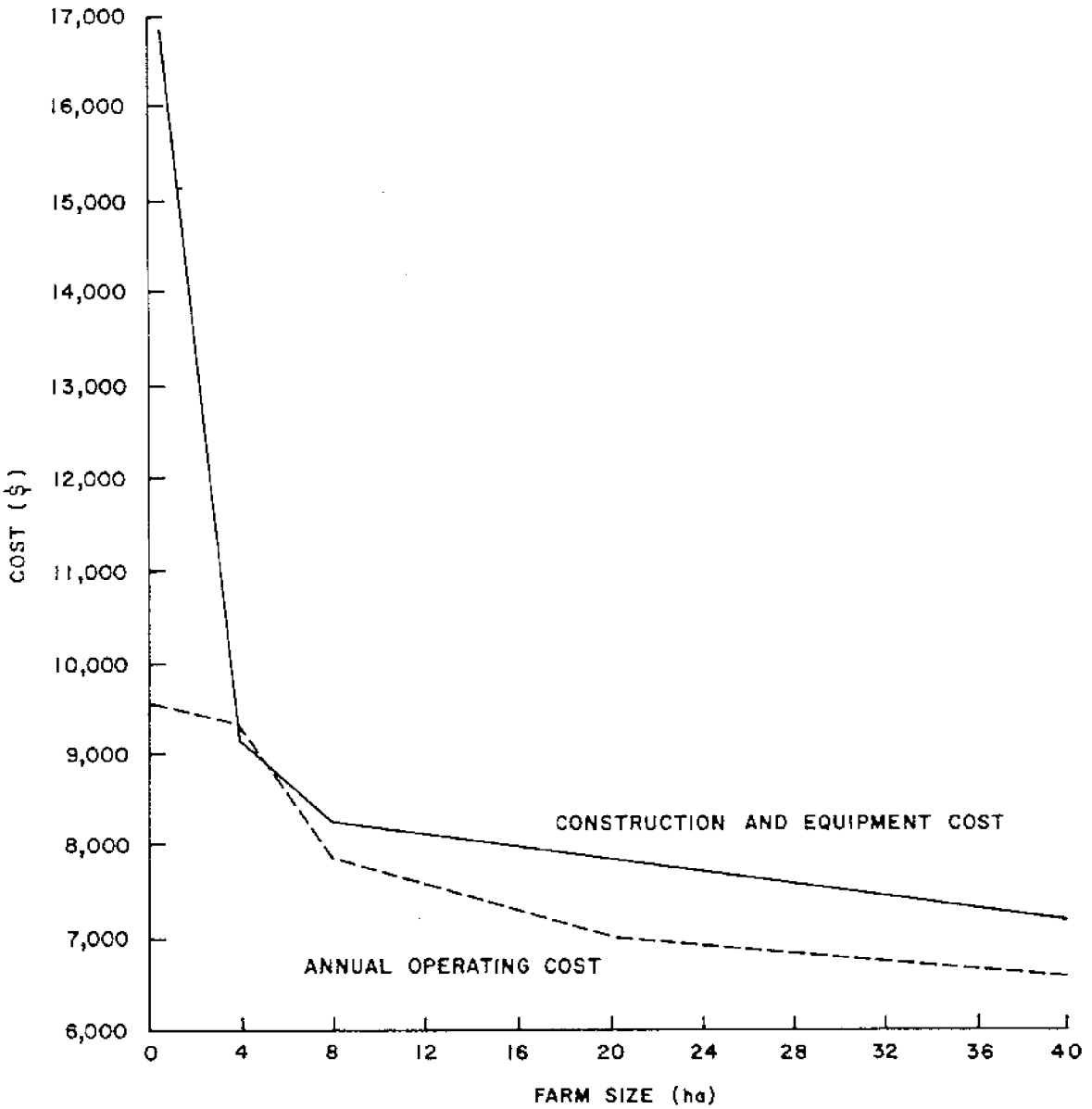


Figure 1. Estimated initial and annual operating cost per 0.4-hectare pond by farm size

## Annual Operation

Ideally, the most accurate approach for estimating annual operating costs is using the farmer's bookkeeping record. But not many farmers have kept detailed records for their operation (a simple form of farm records is presented in Appendix E for reference). The average annual operating costs for different farm sizes were estimated from information collected through personal interviews with Hawaii's commercial prawn farmers and input suppliers. The total annual operating cost per 0.4-hectare pond decreases with an increase in farm size (Table 6 and Figure 1). Labor, feed, interest on initial capital, and land leases are the most important operating cost items (70 percent of the total). Other cost items include

TABLE 6. ESTIMATED AVERAGE ANNUAL OPERATING COSTS PER 0.4-HECTARE POND BY FARM SIZE

| | Operating Costs and Percentage by Farm Size | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0.4 Hectare (1 Acre) | % of Total Cost | 4 Hectares (10 Acres) | % of Total Cost | 8 Hectares (20 Acres) | % of Total Cost | 20 Hectares (50 Acres) | % of Total Cost | 40 Hectares (100 Acres) | % of Total Cost |
| Labor | $1,184 | 12.4 | $3,144 | 33.7 | $2,094 | 26.7 | $1,542 | 21.8 | $1,325 | 20.0 |
| Juveniles* | 520 | 5.4 | 520 | 5.6 | 520 | 6.6 | 520 | 7.4 | 520 | 7.9 |
| Feed | 1,660 | 17.4 | 1,660 | 17.8 | 1,660 | 21.2 | 1,660 | 23.5 | 1,660 | 25.1 |
| Electricity | -- | -- | 207 | 2.2 | 165 | 2.1 | 205 | 2.9 | 153 | 2.3 |
| Lease | 882 | 9.2 | 708 | 7.6 | 708 | 9.0 | 708 | 10.0 | 708 | 10.7 |
| Gasoline and oil | 163 | 1.7 | 81 | 0.9 | 81 | 1.0 | 36 | 0.5 | 27 | 0.4 |
| Maintenance | 382 | 4.0 | 305 | 3.2 | 286 | 3.7 | 267 | 3.8 | 248 | 3.7 |
| Interest | 2,605 | 27.3 | 1,406 | 15.0 | 1,281 | 16.4 | 1,228 | 17.4 | 1,146 | 17.3 |
| Depreciation | 1,652 | 17.3 | 493 | 5.3 | 389 | 5.0 | 357 | 5.0 | 322 | 4.9 |
| Tax | 40 | 0.4 | 40 | 0.4 | 40 | 0.5 | 40 | 0.5 | 40 | 0.6 |
| Insurance | -- | -- | 334 | 3.6 | 232 | 3.0 | 172 | 2.4 | 149 | 2.3 |
| Miscellaneous† | 454 | 4.8 | 445 | 4.8 | 373 | 4.8 | 337 | 4.8 | 315 | 4.8 |
| TOTAL | $9,542 | | $9,343 | | $7,829 | | $7,072 | | $6,613 | |

*For those farms over 20 hectares that produce their own juveniles, $8.00/1,000 was also used in the calculation since no detailed cost data were available.

†5 percent additional operating costs

pond maintenance, insurance, gasoline and oil, and taxes. The following sections provide a brief explanation on how the estimates were calculated.

Labor

At present, Hawaii's prawn farming industry is still a labor-intensive operation; the major operational tasks of harvesting and feeding are done manually. Labor is one of the most important cost items, accounting for nearly 34 percent of the total annual operating expense for a 4-hectare farm and about 20 percent for a 40-hectare farm (Table 6). A 0.4-hectare farm is regarded as a backyard or supplemental type of operation. It is usually integrated with other agricultural activities and most of the labor is provided by family members. The following is the cost estimated for each major labor-demanding activity such as management, feeding, mowing, harvesting, processing, delivery, etc.

Management. It is assumed in this study that each prawn farm which is 4 hectares or more in size needs a specially trained manager and/or technician. Currently, the annual salary of an experienced manager is about $20,000.

Feeding. Feeding is done once a day. At present, feed is loaded onto a pick-up truck and as one man drives alongside a pond, another shovels the feed into the pond. On the average, it is estimated that loading and feeding takes about six minutes per 0.4-hectare pond, or about 12 minutes for a two-man crew.

> Labor cost for feeding per 0.4-hectare pond = 0.2 man-hour/day x 365 days x $5.00/man-hour = $365.00

Mowing. Grass mowing is assumed to be performed only on a monthly basis. About one hour per mowing is required per 0.4-hectare pond by one worker.

> Labor cost for mowing per 0.4-hectare pond = 12 mowings/year x 1 mowing x $5.00/man-hour = $60.00

Harvesting. As mentioned earlier, a three-man crew takes 2.5 hours on the average to harvest a 0.4-hectare pond. About 63 percent of all farms harvest once every four weeks, or 13 times a year. The calculation is based upon the requirements of most existing farmers.

> Labor cost for harvesting per 0.4-hectare pond = 3 men x 2.5 hours/harvest x 13 harvests/year x $5.00/man-hour = $487.50

Processing. Post-harvest handling and processing of prawns vary among farms. Most of the small-scale farmers sell all of their harvested prawns in live or fresh form, whereas large-scale farmers market their products in ice-chilled or frozen form. Processing (freezing, blanching, or icing) and packing takes about one hour of work for two men per harvest.

> Labor cost for processing per 0.4-hectare pond = 13 harvests/year x 2 man-hour/harvest x $5.00/man-hour = $130.00

Delivery. Most prawn farmers deliver their harvest to wholesalers, brokers, or retailers. The amount of labor required for delivery varies with the quantity of prawns harvested, size of a farm, number of harvests, number of trucks used, and distance between the farm and market. In this report, the following assumptions are made in calculating delivery cost: (1) since most of the prawn farms are located along the northern side of Oahu, a round trip from the farm to the market requires about 2.5 hours for a two-man team; (2) only two ponds can be harvested per day; (3) for up to an 8-hectare farm, delivery occurs soon after

harvest for live prawns to be sold at the market; and (4) for larger farms that generally process their harvested prawns, delivery is done once per week or 52 times annually.

> Labor cost for delivery per 0.4-hectare pond = Number of delivery trips x number of trucks used x 2.5 man-hours/delivery/truck x $5.00/man-hour

The labor cost for delivery by farm size is summarized in Table 7.

TABLE 7. CALCULATION OF LABOR COST FOR DELIVERY BY FARM SIZE

| | Farm Size | | | | |
|---|---|---|---|---|---|
| | 0.4 Hectare (1 Acre) | 4 Hectares (10 Acres) | 8 Hectares (20 Acres) | 20 Hectares (50 Acres) | 40 Hectares (100 Acres) |
| Number of delivery trips (per truck) | 13 | 65 | 130 | 52 | 52 |
| Number of trucks | 1 | 1 | 1 | 2 | 3 |
| Man-hours (2.5 hours/trip/truck) | 33 | 163 | 325 | 260 | 390 |
| Cost ($5.00/man-hour) per farm | $ 163 | $ 813 | $1,625 | $1,300 | $1,950 |
| Cost per 0.4-hectare pond | $ 163 | $ 81 | $ 81 | $ 26 | $ 19 |

Total labor cost for all of these activities for each farm size is summarized in Table 8. Management, feeding, and harvesting are the most important cost items for labor. The calculated labor cost per 0.4-hectare pond decreases from $3,144 for a 4-hectare farm to $1,325 for a 40-hectare farm due to the economies of scale.

TABLE 8. SUMMARY OF LABOR COST PER 0.4-HECTARE POND BY ACTIVITY AND BY FARM SIZE

| Activity | Farm Size | | | | |
|---|---|---|---|---|---|
| | 0.4 Hectare (1 Acre) | 4 Hectares (10 Acres) | 8 Hectares (20 Acres) | 20 Hectares (50 Acres) | 40 Hectares (100 Acres) |
| Management | $ – | $2,000 | $1,000 | $ 400 | $ 200 |
| Feeding | 365 | 365 | 365 | 365 | 365 |
| Mowing | 60 | 60 | 60 | 60 | 60 |
| Harvesting | 488 | 488 | 488 | 488 | 488 |
| Processing | – | – | – | 130 | 130 |
| Delivery | 163 | 81 | 81 | 26 | 19 |
| Miscellaneous* | 108 | 150 | 100 | 73 | 63 |
| TOTAL | $1,184 | $3,144 | $2,094 | $1,542 | $1,325 |

*10 percent of total labor cost for a 0.4-hectare farm and 5 percent for larger size farms

## Juveniles

Calculating the cost of juveniles per 0.4-hectare pond is accomplished by multiplying the current stocking rate of between 60 x $10^3$ and 70 x $10^3$ postlarvae per pond times the unit cost of $8.00 per 1,000 postlarvae. (It may cost more for those large farms producing their own postlarvae.)

Electricity

Water pumping is a major electricity consumption item on a farm. The annual cost per farm (Cp) is calculated by multiplying the number of hours operated annually (T) times the amount of kilowatts consumed per hour (KW) and the rate of electricity per kilowatt-hour (Pe), or Cp = T x KW x Pe.

The total number of hours operated annually was calculated by multiplying 24 hours a day times 365 days a year times the number of water pumps used on the farm, whereas the amount of kilowatts consumed per hour was estimated to be about 3 kw for a 5 horsepower (hp) pump, 5 kw for a 10 hp pump, and 8 kw for a 14 hp pump.

Currently, Hawaiian Electric Company determines monthly electricity cost for commercial use on Oahu according to Schedule G rates for agriculture. A customer service fee is initially charged either at $4.00/month or $5.50/month depending upon the type of electrical wiring used. A customer use charge is then added based upon the following Schedule G rates:

| | |
|---|---|
| $.082/kilowatt-hour | first 1,000 hours |
| $.059/kilowatt-hour | next 9,000 hours |
| $.049/kilowatt-hour | over 10,000 hours |

Lastly, fuel cost is added at a rate of $.022867/kilowatt-hour. Thus, annual pumping cost is equal to the total of the cost items mentioned above.

Feed

The annual cost for feeding ($C_f$) was estimated based upon a daily industry average feeding rate ($D_f$) which is about 15.9 kilograms per 0.4 hectare (35 pounds per acre) times the unit cost of feed ($P_f$):

$$C_f = D_f \times P_f \times 365 \text{ days/year.}$$

At present, the unit price (per kilogram) of feed commercially labeled as prawn pellets is approximately $.028 per kilogram ($13.00 per 100 pounds) for bulk purchases, including delivery cost and sales tax.

Interest

A 16 percent interest rate is assessed on the initial amount expended for construction and equipment. The interest rate is based upon current average market rates charged by most private institutions. Public financial institutions, however, charge much lower rates. For example, the Hawaii Department of Agriculture charges 5 percent interest annually on assistance loans of up to $175,000. The federal Small Business Administration charges 9-1/4 percent annual interest on loans up to a maximum of $150,000. The U.S. Department of Agriculture charges 12 percent for its farm owner's loans.

Land lease

Lease agreements vary among publicly and privately owned land. The Hawaii Department of Land and Natural Resources leases state-owned land for approximately 6 percent of its market value or 3.5 percent of the gross income, whichever is greater. Some private landowners calculate the lease by adding a percentage of gross income derived to a base amount; however, no fixed standard formula exists at present. In this study, the lease was calculated

based on 6 percent of the current average market value for agricultural land which is about $10,000 per 0.4 hectare. A 4-hectare or more farm needs only about 0.5 hectare of land per pond (0.4 hectare) with an annual lease of about $708 in comparison to a 0.4-hectare farm which requires 0.6 hectare of land for each pond with an annual lease of $882.

### Pond maintenance

Earthen ponds need major maintenance service every three to five years to remove silt and wastes from the pond bottom and to reconstruct the embankments. The cost of maintenance is about 33 percent of the original construction cost per pond every five years.

### Depreciation

Depreciation cost calculations are based on the estimated economic life of the facilities and equipment as shown in Appendix E. In this report, the straight-line depreciation method was used. Since prawn ponds need to be reconstructed every five years and since the cost of reconstruction is included as an item of the annual operating expenses (pond maintenance), there is no depreciation charge on the pond.

### Insurance

Most prawn farmers initially secure against unexpected accidents by purchasing an annual insurance coverage plan. With such a policy, farmers are generally protected from major liability charges occurring as a result of poor quality products, an accident on the farm, etc. The major areas of coverage include bodily injury, product liability, temporary disability, workmen's compensation, and loss or damage of equipment. Current annual rates for insurance protection are based upon the size of a farm, the type of coverage, and the maximum amount of stipulated coverage.

### Gasoline and oil

The annual fuel and oil expenses per 0.4-hectare pond for varying farm sizes in Hawaii were calculated by adding the expenses for delivery and for other business activities. As previously mentioned, the number of delivery trips needed annually is about 13, 65, 130, 52, and 52 for farm sizes of 0.4, 4, 8, 20, and 40 hectares, respectively. A round trip from a farm to the market distributor is, on the average for most farms on Oahu, about 112 kilometers (70 miles). A truck consumes, on the average, about 1 liter of fuel per 6.3 kilometers. At the present cost of fuel which is $0.34 per liter ($1.30 per gallon), estimated fuel and oil costs for delivery can be calculated as:

$$\text{Gasoline and oil costs per 0.4-hectare pond} = \frac{\text{No. of trips} \times 112 \text{ km} \div 6.3 \text{ km/liter} \times \$0.34/\text{liter} \times \text{No. of trucks}}{\text{Size of the farm in number of 0.4-hectare ponds}}$$

Gasoline and oil expenses for other business activities were estimated based on information obtained from the field survey.

## Taxes

Three kinds of taxes are usually involved in prawn farming:

1. Gross income tax which is 0.5 percent for farm products sold at the wholesale level, or 4 percent at the retail level
2. Property tax which is $15.23 per $1,000 of the net assessment value on Oahu, $7.50 on Maui, $17.90 on Hawaii, and $14.15 on Kauai
3. Corporate income tax which is 5.80 percent on taxable income not over $25,000 and 6.43 percent on taxable income over $25,000, plus 3.08 percent on capital gain

It is important to note that only gross income tax was included in the annual operating cost listed in Table 6. Property tax should be included as a cost item if a prawn farmer owns his land. This is also true for corporate tax if a farm is organized as a corporation.

# RESULTS OF THE ECONOMIC ANALYSIS

As mentioned earlier, the annual production level varies from season to season and between farms. Production per unit of pond, in many cases, increases over time for the first two to three years of operation. Under normal conditions, an annual production level of 907 kilograms per 0.4-hectare pond seems obtainable at the present time after two or three years of operation. In the calculation of break-even price, break-even production, profit, and rate of return, four levels of annual production were used in order to analyze the sensitivity to varying levels: 680, 907, 1,134, and 1,361 kilograms per 0.4-hectare pond (1,500, 2,000, 2,500, and 3,000 pounds per 1-acre pond).

Small farms (less than 8 hectares) usually sell their prawns live and/or fresh and therefore receive a relatively higher price which is currently about $9.37/kilogram ($4.25/pound) with heads on. However, a significant portion of the total production of the industry is sold at a price as low as $7.72/kilogram ($3.50/pound). The weighted average price for the industry is approximately $8.82/kilogram ($4.00/pound) at the present time. In order to show profitable rates of return under different conditions, four levels of farm prices were also used in the calculation: $7.72, $8.27, $8.82, and $9.37 per kilogram with heads on.

## Profit

Profit per 0.4-hectare pond increases with increased production levels and farm sizes (Table 9). At an annual production rate of 680 kilograms/pond all sizes of farms suffer losses. Farms over 8 hectares start making a profit at the production level of 907 kilograms/pond and at the price of $8.82/kilogram. All sizes of farms make a profit at the production level of 1,134 kilograms or more per pond and at the price of $8.82/kilogram.

## Break-even farm price

Given the annual production level per unit of pond and the production cost:

$$\text{Break-even farm price per pond} = \frac{\text{Annual operating cost/pond}}{\text{Annual production/pond}}$$

Based on the above formula, the break-even price can also be defined as production cost per unit of prawn.

TABLE 9. CALCULATED PROFIT PER 0.4-HECTARE POND BY PRODUCTION LEVEL, FARM PRICE, AND FARM SIZE

| Production Level Per 0.4-Hectare Pond in kg (in lbs) | Farm Price | | Profit by Farm Size | | | | |
|---|---|---|---|---|---|---|---|
| | per kg | per lb | 0.4 Hectare (1 Acre) | 4 Hectares (10 Acres) | 8 Hectares (20 Acres) | 20 Hectares (50 Acres) | 40 Hectares (100 Acres) |
| 680 | $7.72 | $3.50 | $ -4,292 | $ -4,093 | $ -2,579 | $ -1,822 | $ -1,363 |
| (1,500) | 8.27 | 3.75 | -3,917 | -3,718 | -2,204 | -1,447 | - 988 |
| | 8.82 | 4.00 | -3,542 | -3,343 | -1,829 | -1,072 | - 613 |
| | 9.37 | 4.25 | -3,167 | -2,968 | -1,454 | - 697 | - 238 |
| 907 | 7.72 | 3.50 | -2,542 | -2,343 | - 829 | - 72 | 387 |
| (2,000) | 8.27 | 3.75 | -2,042 | -1,843 | - 329 | 428 | 887 |
| | 8.82 | 4.00 | -1,542 | -1,343 | 171 | 928 | 1,387 |
| | 9.37 | 4.25 | -1,042 | - 843 | 671 | 1,428 | 1,887 |
| 1,134 | 7.72 | 3.50 | - 792 | - 593 | 921 | 1,678 | 2,137 |
| (2,500) | 8.27 | 3.75 | - 167 | 32 | 1,546 | 2,303 | 2,762 |
| | 8.82 | 4.00 | 458 | 657 | 2,171 | 2,928 | 3,387 |
| | 9.37 | 4.25 | 1,083 | 1,282 | 2,796 | 3,553 | 4,012 |
| 1,361 | 7.72 | 3.50 | 958 | 1,157 | 2,671 | 3,428 | 3,887 |
| (3,000) | 8.27 | 3.75 | 1,708 | 1,907 | 3,421 | 4,178 | 4,637 |
| | 8.82 | 4.00 | 2,458 | 2,657 | 4,171 | 4,928 | 5,387 |
| | 9.37 | 4.25 | 3,208 | 3,407 | 4,921 | 5,678 | 6,137 |

The break-even farm price of prawn decreases with an increase in production level and farm size (Table 10 and Figure 2). Should the production level double, the break-even farm price would reduce by 50 percent. At a production level of 907 kilograms/pond, the break-even farm price of prawn was estimated to be $10.52/kilogram ($4.77/pound) for a 0.4-hectare farm, $8.64/kilogram ($3.92/pound) for an 8-hectare farm, and $7.30/kilogram ($3.31/pound) for a 40-hectare farm. Compared with the current average farm price of about $8.82/kilogram, only farms of 8 hectares or more are in the break-even category at the production level of 907 kilograms/pond.

TABLE 10. CALCULATED BREAK-EVEN FARM PRICE, GIVEN PRODUCTION LEVEL BY FARM SIZE

| Production Level Per 0.4-Hectare Pond in kg (lbs) | Break-even Price by Farm Size in $/kg ($/lb) | | | | |
|---|---|---|---|---|---|
| | 0.4 Hectare (1 Acre) | 4 Hectares (10 Acres) | 8 Hectares (20 Acres) | 20 Hectares (50 Acres) | 40 Hectares (100 Acres) |
| 680 (1,500) | $14.00 ($6.36) | $13.71 ($6.23) | $11.48 ($5.22) | $10.38 ($4.72) | $ 9.70 ($4.41) |
| 907 (2,000) | 10.50 ( 4.77) | 10.28 ( 4.67) | 8.62 ( 3.92) | 7.79 ( 3.54) | 7.28 ( 3.31) |
| 1,134 (2,500) | 8.40 ( 3.82) | 8.23 ( 3.74) | 6.89 ( 3.13) | 6.23 ( 2.83) | 5.83 ( 2.65) |
| 1,361 (3,000) | 7.00 ( 3.18) | 6.84 ( 3.11) | 5.74 ( 2.61) | 5.19 ( 2.36) | 4.84 ( 2.20) |

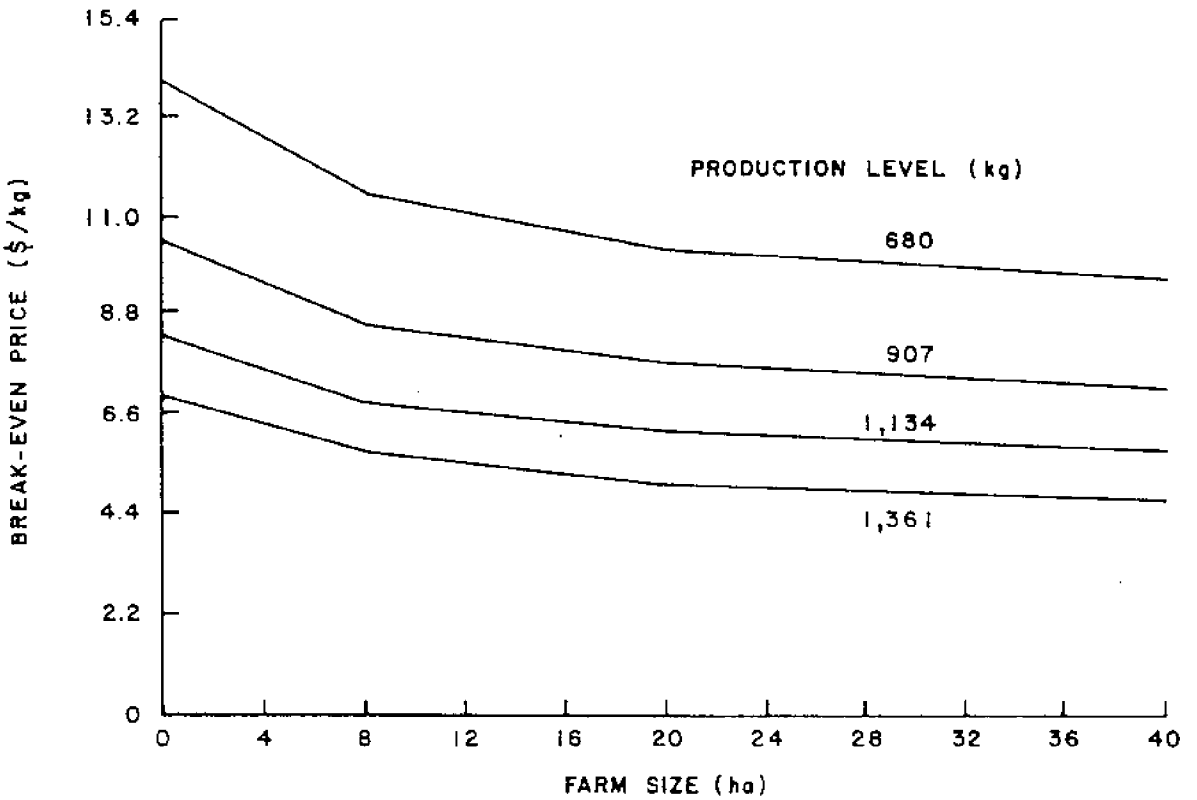


Figure 2. Estimated break-even price by production and farm size

Break-even production level

Given the farm price of prawn and the production cost:

$$\text{Break-even production level/pond} = \frac{\text{Annual operating cost/pond}}{\text{Average farm price/kilogram}}$$

The break-even production level/pond decreases with an increase in farm prices and in farm size (Table 11 and Figure 3). For instance, for an 8-hectare farm, the estimated break-even production level decreases from 1,019 kilograms/pond (2,237 pounds/pond) at the given farm price of $7.72/kilogram to 837 kilograms/pond at the farm price of $9.37/kilogram. Also, at the given farm price of $8.82/kilogram, the estimated break-even production level per pond decreases from 1,085 kilograms for a 0.4-hectare farm to 751 kilograms for a 40-hectare farm.

TABLE 11. CALCULATED BREAK-EVEN PRODUCTION PER 0.4-HECTARE POND, GIVEN FARM PRICES BY FARM SIZE

| Farm Price in $/kg ($/lb) | Break-even Production by Farm Size in kg (lbs) | | | | |
|---|---|---|---|---|---|
| | 0.4 Hectare (1 Acre) | 4 Hectares (10 Acres) | 8 Hectares (20 Acres) | 20 Hectares (50 Acres) | 40 Hectares (100 Acres) |
| $7.72 ($3.50) | 1,239 (2,726) | 1,213 (2,669) | 1,017 (2,237) | 919 (2,021) | 859 (1,889) |
| 8.27 ( 3.75) | 1,157 (2,545) | 1,133 (2,492) | 949 (2,088) | 857 (1,886) | 802 (1,764) |
| 8.82 ( 4.00) | 1,085 (2,386) | 1,062 (2,336) | 889 (1,957) | 803 (1,768) | 751 (1,653) |
| 9.37 ( 4.25) | 1,020 (2,245) | 999 (2,198) | 837 (1,842) | 756 (1,664) | 707 (1,556) |

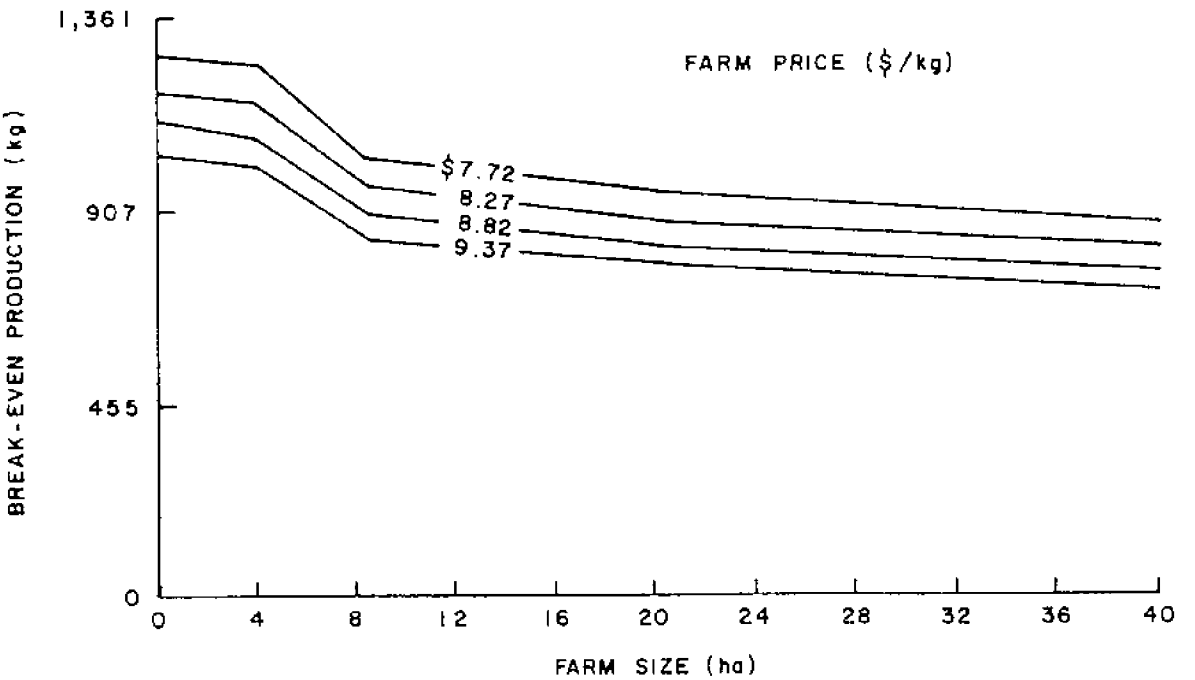


Figure 3. Estimated break-even production per 0.4-hectare pond by farm price and farm size

## Rate of return

Two types of rate of return were calculated in this study:

1. Rate of return on initial investment = $\frac{\text{Annual profit}}{\text{Initial investment}}$

2. Rate of return on annual operating cost = $\frac{\text{Annual profit}}{\text{Annual operating cost}}$

The first type represents the average earning power of the investment in prawn operation and provides the information on number of years required to pay back the initial investment. The second type represents the average earning power of the annual operating capital in prawn production.

Both rates are negative given the annual production level of 680 kilograms/pond and almost all of them are positive at production level of 1,134 kilograms or more per 0.4-hectare pond (Tables 12 and 13). Only farms above 8 hectares in size have positive rates of return at the given level of production of 907 kilograms and at the current average farm price of $8.82/kilogram.

TABLE 12. RATE OF RETURN ON INITIAL INVESTMENT BY PRODUCTION LEVEL, FARM PRICE, AND FARM SIZE

| Production Level Per 0.4-Hectare Pond in kg (in lbs) | Farm Price | | Rate of Return (%) | | | | |
|---|---|---|---|---|---|---|---|
| | per kg | per lb | 0.4 Hectare (1 Acre) | 4 Hectares (10 Acres) | 8 Hectares (20 Acres) | 20 Hectares (50 Acres) | 40 Hectares (100 Acres) |
| 680 | $7.72 | $3.50 | NE* | NE | NE | NE | NE |
| (1,500) | 8.27 | 3.75 | NE | NE | NE | NE | NE |
| | 8.82 | 4.00 | NE | NE | NE | NE | NE |
| | 9.37 | 4.25 | NE | NE | NE | NE | NE |
| 907 | 7.72 | 3.50 | NE | NE | NE | NE | 5.36 |
| (2,000) | 8.27 | 3.75 | NE | NE | NE | 5.94 | 12.28 |
| | 8.82 | 4.00 | NE | NE | 2.08 | 11.91 | 19.21 |
| | 9.37 | 4.25 | NE | NE | 8.17 | 18.32 | 26.13 |
| 1,134 | 7.72 | 3.50 | NE | NE | 11.21 | 21.53 | 29.59 |
| (2,500) | 8.27 | 3.75 | NE | 0.35 | 18.82 | 29.55 | 38.24 |
| | 8.82 | 4.00 | 2.67 | 7.15 | 26.43 | 37.57 | 46.90 |
| | 9.37 | 4.25 | 6.31 | 13.94 | 34.04 | 45.59 | 55.55 |
| 1,361 | 7.72 | 3.50 | 5.58 | 12.58 | 32.51 | 43.98 | 53.82 |
| (3,000) | 8.27 | 3.75 | 9.95 | 20.74 | 41.64 | 53.61 | 64.21 |
| | 8.82 | 4.00 | 14.31 | 28.90 | 50.77 | 63.23 | 74.59 |
| | 9.37 | 4.25 | 18.68 | 37.05 | 59.90 | 72.85 | 84.98 |

*NE = negative

TABLE 13. RATE OF RETURN ON ANNUAL OPERATING COST BY PRODUCTION LEVEL, FARM PRICE, AND FARM SIZE

| Production Level Per 0.4-Hectare Pond in kg (in lbs) | Farm Price | | Rate of Return (%) | | | | |
|---|---|---|---|---|---|---|---|
| | per kg | per lb | 0.4 Hectare (1 Acre) | 4 Hectares (10 Acres) | 8 Hectares (20 Acres) | 20 Hectares (50 Acres) | 40 Hectares (100 Acres) |
| 680 (1,500) | $7.72 | $3.50 | NE* | NE | NE | NE | NE |
| | 8.27 | 3.75 | NE | NE | NE | NE | NE |
| | 8.82 | 4.00 | NE | NE | NE | NE | NE |
| | 9.37 | 4.25 | NE | NE | NE | NE | NE |
| 907 (2,000) | 7.72 | 3.50 | NE | NE | NE | NE | 5.85 |
| | 8.27 | 3.75 | NE | NE | NE | 6.05 | 13.41 |
| | 8.82 | 4.00 | NE | NE | 2.18 | 13.12 | 20.97 |
| | 9.37 | 4.25 | NE | NE | 8.57 | 20.19 | 28.53 |
| 1,134 (2,500) | 7.72 | 3.50 | NE | NE | 11.76 | 23.73 | 32.32 |
| | 8.27 | 3.75 | NE | 0.34 | 19.75 | 32.57 | 41.77 |
| | 8.82 | 4.00 | 4.80 | 7.03 | 27.73 | 41.40 | 51.22 |
| | 9.37 | 4.25 | 11.35 | 13.72 | 35.71 | 50.24 | 60.67 |
| 1,361 (3,000) | 7.72 | 3.50 | 10.04 | 12.38 | 34.12 | 48.47 | 58.78 |
| | 8.27 | 3.75 | 17.90 | 20.41 | 43.70 | 59.08 | 70.12 |
| | 8.82 | 4.00 | 25.76 | 28.44 | 53.28 | 69.68 | 81.46 |
| | 9.37 | 4.25 | 33.62 | 36.47 | 62.86 | 80.29 | 92.80 |

*NE = negative

## COMPARISON WITH SELECTED AGRICULTURAL CROPS

It is difficult to make a direct economic comparison between freshwater prawn farming and agricultural crop production unless the economic data are collected for the same time period and the cost items included are comparable. Table 14 provides some information on profit and rate of return on operating cost for selected local agricultural crops on a 0.4-hectare basis. In most cases, the rate of return of these agricultural crops is relatively high (over 50 percent) compared with that of freshwater prawn farming at the present level of production. However, the cost data for agricultural crops were based mostly on case studies and, therefore, do not represent the average situation. Also, those cost data were collected in 1978 for the production year of 1977. The rapid change in input cost and output prices is likely to out-date those studies. Hence, they serve only as a reference.

TABLE 14. PROFIT AND RATE OF RETURN OF SELECTED AGRICULTURAL CROPS IN HAWAII (ON A 0.4 HECTARE BASIS)

| | Profit | Rate of Return on Operating Cost (%) |
|---|---|---|
| Taro (Kauai)* (15 months—one crop) | $ 2,002 | 52 |
| Cucumber (Hawaii)† (3 crops a year) | 13,986 | 53 |
| Bell pepper (Kauai)† (1 crop a year) | 7,185 | 54 |
| Radish (Hilo)† (12 crops a year) | 1,524 | 17 |
| Anthurium (Hawaii)† (5th year of operation) | 4,140 | 66 |
| Eggplant (Kauai)† | 4,855 | 27 |

*Data from The Economics of Wetland Taro Production in Hawaii by G.R. Vieth, B.W. Begley, and W.Y. Huang, Department of Agricultural and Resource Economics, University of Hawaii (in press)

†Data from Farm Management Reports, Cooperative Extension Service, College of Tropical Agriculture, University of Hawaii

## SUMMARY AND CONCLUSIONS

Based on the previous analysis, it can be concluded that the profit and the rate of return of freshwater prawn farming increase as the farm size increases under normal management conditions. This is also true when the level of production and farm price increase. Large farms benefit from greater efficiency in resource utilization, especially labor. Small farms can survive only when operated as a family venture and when combined with other agricultural or aquacultural production activities. The results of the previous analysis indicates that an 8-hectare farm is likely to be a fairly economical starting point for a commercial prawn operation at the current average production level of 907 kilograms per 0.4-hectare pond and at the average farm price of $8.82/kilogram.

The cost of some inputs have been escalating during recent years. Inflation, higher energy costs and wages, increasing land values, and water use restrictions have all placed additional burdens upon future developments of the prawn industry in Hawaii. The cost of production per 0.4-hectare pond, based on an 8-hectare farm increased about 37 percent between 1976 and 1980, while the average farm price of prawn increased only about 30 percent. In addition, the current average production level per pond (907 kilograms) is much less than that projected four years ago (1,364 to 1,590 kilograms), but is still much higher than that of Thailand and Taiwan which is less than 455 kilograms. A higher pond productivity level, as previously projected, may be within reach as hatchery production improves and as research and experience to help the industry develop new technologies and better ways of raising prawns progresses.

Prawn farming in Hawaii is still a labor-intensive operation. Harvesting and feeding are mostly done manually. The cost of production would be reduced significantly if prawn farms could be efficiently mechanized and a better feed and more efficient feeding practice could be developed. In addition, better pond design, improved stocking schedules and pond management, polyculture with other species and/or land-based animals, genetic improvements, and better processing techniques are important research areas to be continued in order to increase unit production and reduce cost. Improvements in these aspects, together with market development, should improve the competitive position of the industry among other investment alternatives in Hawaii and should attract more investors and landowners into this industry.

Hawaii has been contributing in areas of prawn farming technology and expertise in many countries, especially those in central America and South East Asia. In the long run, should the local prawn industry keep growing, the island-produced prawns will have to compete in the world market with some of those countries where weather is warmer and where abundant, inexpensive land and labor are available. However, if production cost can be reduced through ongoing research efforts, Hawaii may well be able to take advantage of its location, technological knowledge, uniform and high product quality, as well as its air-freighting amenities, to build an export industry of *Macrobrachium rosenbergii*.

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# APPENDICES

Appendix A. Status of *Macrobrachium* Culture in Various Countries (After Rabanal, 1980)

| Country | Species | Type of Culture | Commercial Production Data |
|---|---|---|---|
| Argentina | *M. borellii* | Laboratory culture | None |
| Australia | *M. autraliense* | Laboratory hatching | None |
| Bangladesh | *M. rosenbergii* | Hatching and pond production programmed | None |
| Barbados West Indies | *M. carcinus* | Laboratory hatching | None |
| Brazil | *M. acanthurus* | Experimental culture | None |
| | *M. carcinus* | Experimental culture | None |
| Burma | *M. rosenbergii* | Experimental hatching | None |
| Colombia | *M. surinamicum* | Laboratory culture | None |
| | *M. americanum* | Laboratory culture | None |
| Ecuador | *M. diguiti* | Experimental culture | None |
| Ghana | *M. vollenhoveni* | Culture planned | None |
| Guam | *M. rosenbergii* | Experimental culture tried | None |
| India | *M. rosenbergii* *M. malcolmsonii* | Experimental hatching | None |
| Indonesia | *M. rosenbergii* | Hatching and grow-out | None |
| Israel | *M. rosenbergii* | Experimental culture | None |
| Japan | *M. rosenbergii* | Laboratory hatching | None |
| Kampuchea | *M. rosenbergii* | Laboratory hatching | None |
| Laos | *M. rosenbergii* | Experimental culture | None |
| Malaysia | *M. rosenbergii* | Hatcheries established | None |
| Mauritius | *M. rosenbergii* | Hatching and grow-out | 17 ha grow-out ponds produce 10 tons/year |
| Mexico | *M. americanum* | Experimental culture | None |
| | *M. rosenbergii* | Hatching and grow-out | None |
| Palau | *M. rosenbergii* | Experimental culture | None |
| Puerto Rico | *M. rosenbergii* | Commercial culture | 9 ha of ponds |
| Sri Lanka | *M. rosenbergii* | Hatchery and grow-out ponds planned | None |
| Tahiti | *M. rosenbergii* | Experimental culture | None |
| Taiwan | *M. rosenbergii* | Commercial culture | 18 million PL<br>30 farms<br>165 ha of ponds<br>65 tons of prawns (1980) |
| Thailand | *M. rosenbergii* | Commercial culture | 26 million PL<br>455 farms<br>375 ha of ponds<br>350 tons of prawns (1980) |
| United Kingdom | *M. rosenbergii* | Laboratory hatching | None |
| Uruguay | *M. borellii* | Laboratory culture | None |
| Venezuela | *M. acanthurus* | Experimental culture | None |
| | *M. amazonicum* | Experimental culture | None |
| Vietnam | *M. rosenbergii* | Hatchery planned | None |
| Western Samoa | *M. rosenbergii* | Experimental culture | None |

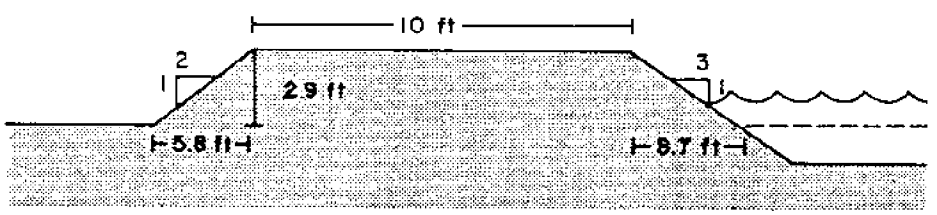
Appendix B. Estimating the Cost of Constructing a 1-Acre (0.4-Hectare) Earthen Pond*

Given:

A. Site Selection--windward side of Oahu
   Soil type: clay loam or silty clay, both with 85 percent retention
   Bedrock: greater than 5 feet deep
   Seepage rate: 2 to .63 inches per hour
   Slope: 0 percent

B. Pond Design--1-acre rectangular pond
   Wetted area: 396 feet x 110 feet or 43,560 feet$^2$
   Dry area: 384 feet x 98 feet or 37,632 feet$^2$
   Slope: lengthwise of about less than 1°
   Water depth: 3.0 feet to 3.5 feet
   Berms: 10.0 feet wide x 2.9 feet high with inner slope ratio of 3:1 (horizontal:vertical); with outer slope ratio of 2:1 (horizontal: vertical)
   Berm height: approximately 1 foot above the water surface

Cross-Sectional View of Embankments




Computing cross-sectional area of the embankment ($A_E$):

$A_E$ = (area of the rectangle) + (area of the triangles)
= (2.9 feet)(10 feet) + 1/2(5.8 feet)(2.9 feet) + 1/2(2.9 feet)(8.7 feet)
= 50.025 feet$^2$

To calculate the volume of soil needed for embankments ($V_E$):

$V_E$ = (perimeter of the cut) x ($A_E$)
= [(384 feet)(2) + (98 feet)(2)] (50.025 feet$^2$)
= (964 feet)(50.025 feet$^2$)
= 48,224.1 feet$^3$
= 1,786.08 yards$^3$

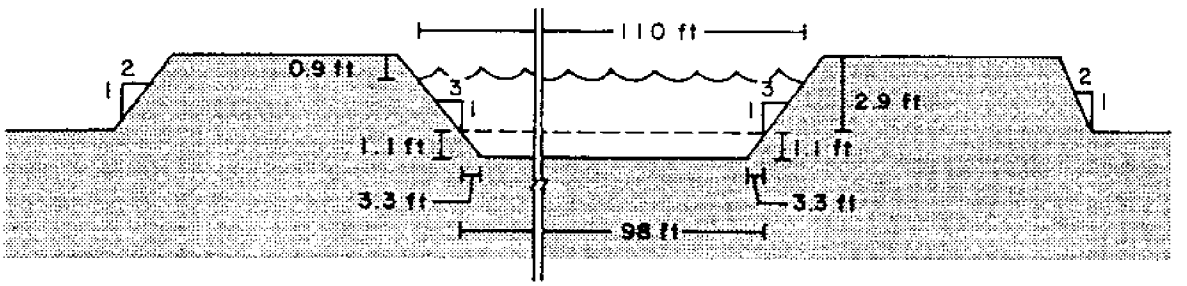
Note: 27 feet$^3$ = 1 yards$^3$

*Data not given in metric units. Use the following table to convert.
1 acre = 0.4 hectare
1 foot = 0.3 meter
1 yard = 0.9 meter

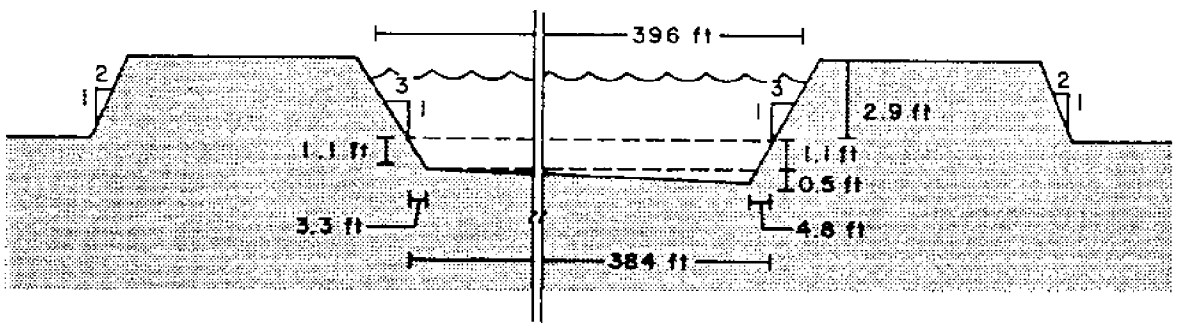
Compaction cost of the embankments ($C_E$) @ \$2.00/yards$^3$:

$C_E$ = ($V_E$)(\$2.00/yards$^3$)
= (1,786.08 yards$^3$)(\$2.00/yards$^3$)
= \$3,572.16/acre

Cross-Sectional View of the Width




Cross-Sectional View of the Length




Computing the area of the cut ($A_C$)

$A_C$ = length x width
= (384 feet)(98 feet)
= 37,632 feet$^2$

Computing the volume of soil excavated by the depth of cut with a less than 1° slope ($V_{EX}$):

$V_{EX}$ = ($A_C$)(1.1 feet) + ($A_C$)(.5 feet)
= 41,395.2 feet$^3$ + 18,816 feet$^3$
= 60,211.2 feet$^3$

Calculating the total volume of soil excavated ($V_T$):

$V_T$ = ($V_{EX}$) - [inner sloped areas of the embankments with a 3:1 slope ratio (horizontal:vertical)]
= 60,211.2 feet$^3$ - [1/2(3.3 feet)(1.1 feet) + 1/2(1.5 feet)(.5 feet)] (964 feet)
= 60,211.2 feet$^3$ - 2,111.16 feet$^3$

= 58,100.04 feet$^3$
= 2,151.85 yards$^3$

Note: With an 85 percent retention of soil excavated, 58,100.04 feet$^3$ = 49.385.034 feet$^3$ adequate volume for 48,224.1 feet$^3$ of soil needed for embankments.

Excavation cost ($E_C$) @ \$1.00/yards$^3$

$E_C$ = ($V_T$)(\$1.00/yards$^3$)
= (2,151.85 yards$^3$)(\$1.00/yards$^3$)
= \$2,151.85/acre

Therefore, total construction cost ($T_C$)

$T_C$ = $E_C + C_E$
= \$2,151.85 + \$3,572.16
= \$5,724.01/acre

Appendix C. Amount of Equipment Required Per Farm by Farm Size

| | Farm Size | | | | |
|---|---|---|---|---|---|
| | 0.4 Hectare (1 Acre) | 4 Hectares (10 Acres) | 8 Hectares (20 Acres) | 20 Hectares (50 Acres) | 40 Hectares (100 Acres) |
| Net | 1 | 2 | 2 | 4 | 8 |
| Holding and transporting tank | 1 | 1 | 1 | 2 | 3 |
| Portable pump | 1 | 1 | 1 | 2 | 3 |
| Mowing machine | 1 (small) | 1 | 1 | 2 | 3 |
| Truck | 1 (3/4 ton) | 1 (3/4 ton) | 1 (3/4 ton) | 1 (3/4 ton)<br>1 (1-1/2 ton) | 2 (3/4 ton)<br>1 (1-1/2 ton) |
| Freezer | -- | -- | -- | 1 (small) | 1 (large) |
| Water pump | -- | 1 | 1 | 2 | 3 |
| | | (500 gpm, 5 hp) | (1,000 gpm, 10 hp) | (1,500 gpm, 14 hp) | (2,000 gpm, 14 hp) |
| Oxygen meter | 1 | 1 | 1 | 2 | 2 |
| pH meter | 1 | 1 | 1 | 2 | 2 |
| Ice machine | -- | 1 | 1 | 1 | 1 |

Appendix D. Estimated Average Construction and Equipment Costs Per Farm by Farm Size

| | Cost by Farm Size | | | | |
|---|---|---|---|---|---|
| | 0.4 Hectare (1 Acre) | 4 Hectares (10 Acres) | 8 Hectares (20 Acres) | 20 Hectares (50 Acres) | 40 Hectares (100 Acres) |
| Construction | | | | | |
| Pond | $ 5,724 | $45,790 | $ 85,860 | $200,350 | $372,100 |
| PVC | 295 | 10,180 | 31,740 | 79,350 | 158,700 |
| Gate | 800 | 8,000 | 16,000 | 40,000 | 80,000 |
| Storage | 150 | 1,000 | 2,000 | 15,000 | 30,000 |
| Subtotal | 6,969 | 64,970 | 135,600 | 334,700 | 640,800 |
| Equipment* | | | | | |
| Seine and net | 869 | 1,740 | 1,640 | 3,500 | 7,000 |
| Holding and transporting tanks | 400 | 1,000 | 1,000 | 2,000 | 3,000 |
| Portable pump | 300 | 600 | 600 | 1,200 | 1,800 |
| Mowing equipment | 300 | 10,000 | 10,000 | 10,000 | 10,000 |
| Truck | 7,000 | 7,000 | 7,000 | 15,000 | 22,000 |
| Freezer | -- | -- | -- | 10,000 | 10,000 |
| Water pump | -- | 1,500 | 3,000 | 6,000 | 9,000 |
| Oxygen meter | 700 | 700 | 700 | 1,400 | 1,400 |
| pH meter | 150 | 150 | 150 | 300 | 300 |
| Ice machine | -- | 3,000 | 3,000 | 3,000 | 3,000 |
| Miscellaneous† | 486 | 1,285 | 1,504 | 2,620 | 3,875 |
| Subtotal | 10,205 | 26,975 | 31,594 | 55,020 | 81,375 |
| TOTAL | $17,174 | $91,945 | $167,194 | $389,720 | $722,175 |

*The amount of equipment needed for the varying farm sizes is listed in Appendix C.
†5 percent of the total equipment cost

## Appendix E. A Record Journal for Prawn Farming

A simplified accounting notebook for items paid and received

Input Costs

a. Daily variable items

(includes the expected and unexpected costs for juveniles, feed, pesticides, temporary labor, electricity, fuel and oil, water use, maintenance and repair, etc.)

| Date | Pond No. | Items (specify) | Quantity | Unit Price | Total Cost |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | Subtotal | |

b. Fixed items

(includes lease, loan and interest payments, salaries for permanent personnel staffs, taxes, insurance, etc.)

| Date | Items (specify) | Monthly Cost | Annual Cost |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | Subtotal | |

Revenue and Production

| Date | Pond No. | Quantity Harvested | Unit Price | Total Revenue |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | Subtotal | |

## ANNUAL SUMMARY

Operating Costs

a. Variable costs

| Pond No. | Items (specify) | Quantity | Annual Costs |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | TOTAL | |

b. Fixed costs

(includes depreciation on facilities and equipments)

| Pond No. | Items (specify) | Quantity | Annual Costs |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | TOTAL | |

Revenue

a. Quantity and value of production

| Pond No. | Size of Pond | Yield in lbs/kg | Production Value |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | TOTAL | |

a. Total variable costs: $ _____

b. Total fixed costs: $ _____

1. Annual Operating Expenses: $ _____
(add lines a and b)

2. Annual Revenue: $ _____

3. Gross Profit: $ _____
(subtract line 2 from line 1)

Appendix F. Annual Depreciation Per 0.4-Hectare Pond by Farm Size

| | Life (in years) | 0.4 Hectare (1 Acre) | 4 Hectares (10 Acres) | 8 Hectares (20 Acres) | 20 Hectares (50 Acres) | 40 Hectares (100 Acres) |
|---|---|---|---|---|---|---|
| Construction | | | | | | |
| Pond | -- | -- | -- | -- | -- | -- |
| PVC | 10 | 30 | 102 | 159 | 159 | 159 |
| Gate | 20 | 40 | 40 | 40 | 40 | 40 |
| Storage | 15 | 10 | 4 | 7 | 20 | 20 |
| Equipment | | | | | | |
| Seine and net | 3 | 290 | 58 | 29 | 23 | 23 |
| Holding and transporting tanks | 10 | 40 | 3 | 1 | 4 | 3 |
| Portable pump | 10 | 30 | 6 | 3 | 2 | 2 |
| Mowing equipment | 10 | 30 | 100 | 50 | 20 | 10 |
| Truck | 7 | 1,000 | 100 | 50 | 43 | 31 |
| Freezer | 15 | -- | -- | -- | 13 | 13 |
| Water pump | 10 | -- | 15 | 15 | 12 | 9 |
| Oxygen meter | 10 | 70 | 7 | 4 | 3 | 1 |
| pH meter | 10 | 15 | 2 | 1 | 1 | 1 |
| Ice machine | 10 | -- | 30 | 15 | 6 | 3 |
| Miscellaneous | 5 | 97 | 26 | 15 | 11 | 8 |
| TOTAL | | 1,652 | 493 | 389 | 357 | 322 |